National Park Service
U.S. Department of the Interior

Crater Lake National Park

Response of Wildlife to Forest Restoration Activities in the Panhandle Region of Crater Lake National Park

2015 Preliminary Report

ON THE COVER
Photograph of western red-backed vole (*Myodes californicus*), northern spotted owl (*Strix occidentalis*) and fisher (*Pekania pennanti*) at Crater Lake National Park.

Photographs by Sean Mohren

Response of Wildlife to Forest Restoration Activities in the Panhandle Region of Crater Lake National Park

2015 Preliminary Report

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Acknowledgments

We would like to thank the NPS Fire Management program and the Crater Lake Natural History Association for helping support us in this important endeavor. Specifically, we would like to thank the CRLA Fire Management Officer, Greg Funderburk, for your help in making this project happen. This project could not have been as successful as it was without the help of a dedicated and hardworking field crew; as such we would like to thank Dorsey Burger, Corinne Ross, and Alan Tomazewski for all their effort on this project.

Introduction

Crater Lake National Park acquired the 973 acre Annie Creek extension known as the "Panhandle" in 1932 from the US Forest Service. This addition was added to the park to secure a more attractive entrance by protecting the old-growth "Yellow Pine" forest (47 Stat. 155--May 14, 1932). At the time of acquiring this piece of land, the management strategy for wildfires was to rigorously suppress all ignitions to prevent loss of forest habitat and to ensure the safety of Park visitors and property. The result of this action converted an old-growth ponderosa pine (*Pinus ponderosa*) dominated forest into a dense mixed conifer forest composed of shade-tolerant species that no longer functions in its original state or natural capacity (CRLA 2004). The current stand of forest now has increased tree densities, higher live and dead fuel loading, shifts in composition from pine to less fire resistant fir species, and reduced understory diversity (Agee 1993, Agee 1998, Merschel 2013). The net result is an increase in density-dependent mortality of old trees (especially ponderosa and sugar pines), increased risk of insect and disease outbreak, lack of new overstory pine recruitment, reduced structural diversity, and an increased risk of higher severity fire (Agee 1993).

In an effort to restore the area back to a more natural state, prescribed burning began in the Panhandle in 1976 and lasted until 2003; the results of this effort caused high mortality of old growth ponderosa pine, the species that they were trying to promote, along with minimal reduction (and even increases) in post-treatment fuel loadings (Swezy and Agee 1988, Swezy and Agee 1991, Perrakis and Agee 2006, Clark 2009). These results are not uncommon in forests following several decades of fire exclusion: poor tree vigor in dense stands reduces survival rates after fire injury, accumulation of heavy duff mounds damage roots when burned, insect and disease activity are high, and heavy fuel loads make controlling fire behavior and crown scorch difficult (Perrakis and Agee 2006, Hood 2010). The Park is now proposing to implement a silviculture-based restoration treatment using mechanical tree removal as an alternative to restore forest composition and structure. The objectives of the restoration project are to improve the probability of survival of old, shade-intolerant trees, reduce the probability of high severity fire, increase landscape-scale heterogeneity, and promote regeneration of ponderosa pine.

In response to this effort, the wildlife team at Crater Lake National Park began surveying the Panhandle region of the Park for rare and threatened species including the northern spotted owl (*Strix occidentalis caurina*), Sierra Nevada red fox (*Vulpes vulpes necator*), and fisher (*Pekania pennanti*). The northern spotted owl was listed at "threatened" under the Endangered Species Act by the USFWS in 1990 and has been on a steady decline in the Park (USDI 1990, Mohren 2015a). The fisher is a Federal Candidate species and is currently being reviewed to be listed as "threatened" in 2016 by the USFWS (USFWS 2014). While not abundant, the fisher has been documented occupying Crater Lake National Park during the summer and winter months (Mohren 2015b, Mohren 2015c). The Sierra Nevada red fox is a rare subspecies of fox that was thought to only occur in 2 locations in California when it was petitioned to be listed in 2011. More recent surveys have documented a few individuals in Oregon including Crater Lake National Park (Mohren 2015b, Mohren 2015c). Upon review for listing, the USFWS subdivided this population of red fox into two distinct population segments, one in southern California and one in northern California and Oregon.

It was their determination that the northern distinct population segmented, which includes the population in Crater Lake National Park, did not warrant protection under the Endangered Species Act at this time (USFWS 2015). Ultimately, we want to ensure the planned forest restoration project does not have any immediate or long-term negative effects to these rare species.

In addition to rare species surveys, the wildlife team is also taking this opportunity to examine the effects of this forest rehabilitation project on the rodent (mice, voles, shrews, and woodrats) and small mammal (chipmunks and squirrels) community. Crater Lake National Park is thought to be home to five mice, seven voles, six shrews, two woodrats, five chipmunks, and four squirrel species (Table 1) that have the potential to occur within the project area. This group of species plays a critical role in the overall health of the ecosystem in and around Crater Lake National Park. Small mammals and rodents make up an important part of the food web and are often relied upon as a food source by both common and rare species of the Park such as red fox, spotted owls, and pine marten. They are partially responsible for distributing nuts, seeds, and fungi throughout the forest. In addition, they assist with the aeration of the soils through burrow development.

The overall goal of this project is to better understand the effects of this restoration effort on the rodent and small mammal community in the Panhandle region of Crater Lake National Park and to ensure the project does not have any short or long-term negative impacts to rare wildlife species. The objectives include: 1) understanding the use of the Panhandle area by rare species including the Northern spotted owl, fisher, and Sierra Nevada red fox; 2) determining the diversity of rodents and small mammals in the Panhandle before and after the restoration project; and 3) examining the change in abundance and distribution of rodents and small mammals after the restoration project is implemented.

Table 1. Rodent and small mammal species thought to occupy Crater Lake National Park.

Taxon	Common Name	Scientific Name
Chipmunks	Yellow-pine Chipmunk	*Tamias amoenus*
Chipmunks	Least Chipmunk	*Tamias minimus*
Chipmunks	Allen's Chipmunk	*Tamias senex*
Chipmunks	Siskiyou Chipmunk	*Tamias Siskiyou*
Chipmunks	Townsend''s Chipmunk	*Tamias townsendii*
Squirrels	Northern Flying Squirrel**	*Glaycomys sabrinus*
Squirrels	Western Gray Squirrel**	*Sciurus griseus*
Squirrels	Golden-mantled Ground Squirrel	*Spermophilus lateralis*
Squirrels	Douglas Squirrel**	*Tamiasciurus douglasii*
Mice	House Mouse	*Mus musculus*
Mice	Great Basin Pocket Mouse*	*Perognathus parvus*
Mice	Deer Mouse	*Peromyscus maniculatus*
Mice	Western Jumping Mouse	*Zapus princeps*
Mice	Pacific Jumping Mouse	*Zapus trinotatus*

Table 1 cont. Rodent and small mammal species thought to occupy Crater Lake National Park.

Taxon	Common Name	Scientific Name
Voles	Western Red-backed Vole	*Clethrionomys californicus*
Voles	Long-tailed Vole	*Microtus longicadus*
Voles	Montane Vole	*Microtus montanus*
Voles	Creeping Vole	*Microtus oregoni*
Voles	Richardson's Vole	*Microtus richardsoni*
Voles	Heather Vole	*Phenacomys intermedius*
Voles	Townsend's Vole	*Microtus townsendii*
Shrews	Pacific Marsh Shrew*	*Sorex bendirii*
Shrews	Pacific Shrew	*Sorex pacificus*
Shrews	Water Shrew	*Sorex palustris*
Shrews	Fog Shrew	*Sorex sonomae*
Shrews	Trowbridge's Shrew	*Sorex trowbridgii*
Shrews	Vagrant Shrew	*Sorex vagrans*
Woodrats	Bushy-tailed Woodrat	*Neotoma cinerea*
Woodrats	Dusky-footed Woodrat	*Neotoma fuscipes*

* Listed as "Probably Present" on Crater Lake National Park's species list

** Sampling methods used on this project would likely not document these species

Methods

Study Area

The Panhandle region of Crater Lake National Park is approximately 3.92 km^2 in size and is located in the southeast portion of the Park (Figure 1). It is a relatively flat area with elevation ranging from approximately 1330-1465 meters. The exception to the terrain is a steep canyon created by the perennial Annie Creek that bisects the area. The area is composed of a mixed-conifer forest that is dominated by ponderosa pine and white fir (*Abies concolor*), with sugar pine (*Pinus lambertiana*) and lodgepole pine (*Pinus contorta*) commonly found throughout (Stanton 2009). The dominant shrubs are tobacco brush (*Ceanothus velutinus*) and greenleaf manzanita (*Arctostaphylos patula*) which mainly occurs in abundance along the southern portions of the Panhandle. In addition to the mixed conifer forest, a small stand of quaking aspen (*Populus tremuloides*) and black cottonwood (*Populus trichocarpa*), approximately 0.03 km^2 in size, is located in the northwest portion of the area and is currently being encroached by conifers. Due to fire suppression, the last natural fire in this area was in the early 1900s (Stanton 2009). Prescribed fire treatments started in 1976 in an attempt to restore the natural landscape after the perception of fire changed in support of carefully managed fires for ecosystem restoration (Swezy and Agee 1988). The prescribed fire treatments stopped once it was shown that they were contributing to the death of large, mature ponderosa pines, the species the Park was trying to protect (Sweezy and Agee 1988). Remnants of these efforts can still be seen through old wood piles, fire lines, and roads that are visible throughout the area. Other factors that likely influence the wildlife in this area includes Highway 62 which bisects the Panhandle, a small maintenance yard where equipment is stored, and a powerline corridor that is currently minimally maintained.

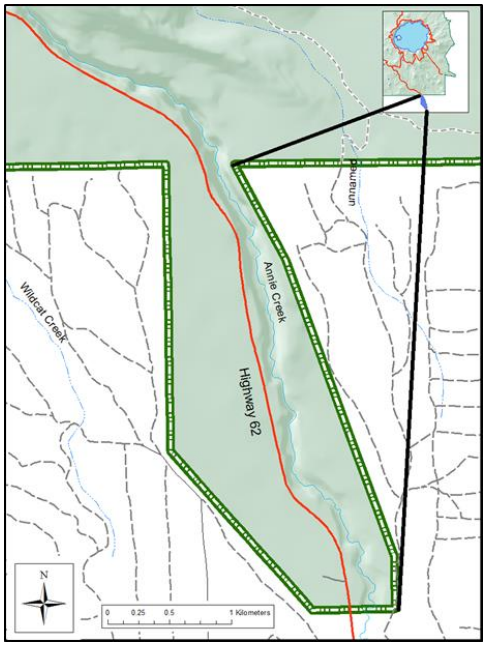

Figure 1. The "Panhandle" area of Crater Lake National Park located in the southeast portion of the Park.

The forest restoration project planned for this area will include various treatments affecting approximately 507 acres on the west side of Highway 62. Five treatment methods will be used as part of this project and include:

- Radial Release: Remove young conifers (size TBD) beneath and adjacent to the crown radius of old-growth pines. This reduces direct competition for soil moisture and nutrients within the rooting zone of the old trees and increases vigor.

- Reserve/Retention Patches: Designated areas of varying size where no cutting will occur.

- Patch/Gap Cuts: Small openings of various size, created to promote ponderosa pine regeneration and growth (typically near remnant seed trees in dense fir), and increase understory cover and structural diversity in homogenous stands.

- Structural Thin: A variable density thin designed to reduce basal area, stand density and ladder fuels of shade-tolerant conifers throughout the "matrix" of the project area (i.e., in areas not designated as radial release, reserve or patch cuts). Variable cutting guidelines ensure spatial heterogeneity and uneven spacing while reducing *average* stand volume to carrying capacity thresholds.

- Special habitats: Includes a variety of special modifications to the above elements where specific habitat features are encountered (such as aspen or phenotypically rust-resistant five-needle pines).

Northern Spotted Owl Surveys

Spotted owl surveys followed the methodologies described in the 2012 revised version of the USFWS 2011 "Protocol for Surveying Proposed Management Activities that may Impact Northern Spotted Owls" (USFWS 2011a). As part of a planned fuels treatment in an area of the Park just north of this project area we began surveying for northern spotted owls in 2010. While not conducted specifically for this project, the layout of the survey locations included the area where this restoration project is planned to be implemented and therefore the results of those surveys are presented in this paper. In addition to these surveys, the survey route was expanded to include two additional calling points to ensure the entire project area was being adequately sampled (Figure 2).

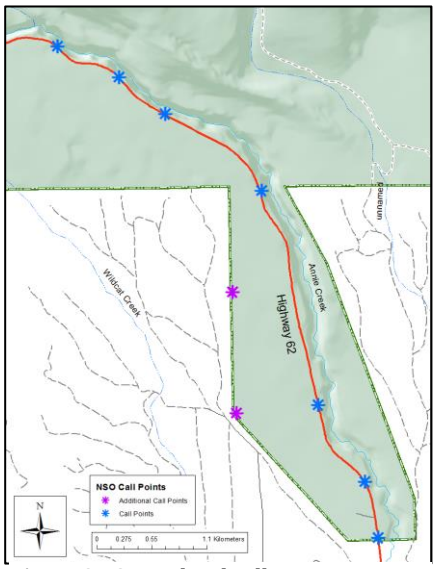

Figure 2. Spotted owl calling stations. Blue stations were sites surveyed before 2014. After 2014 both blue and purple sites were surveyed.

Over the past 6 years we conducted day and night time spotted owls surveys 3-6 times per year along this route. Spotted owl calls were broadcasted for 10 minutes at each call point using a MP3 player and broadcast wildlife caller. If a spotted owl response occurred, the bird was located and we attempted to determine its status. Occupancy, pair status, nesting status and reproduction were determined

using Forsman's "Standardized Protocols for Gathering Data on Occupancy and Reproduction in Spotted Owl Demographic Studies" and Seaman's "Standards and Guidelines for Determining Pair, Nesting, and Reproductive Status of Spotted Owls in National Parks" (Seaman 1993, Forsman 1995). As part of this effort we attempt to identify owls based on color bands and determine the sex and age class (juvenile, sub-adult, adult) when possible. We discontinued or altered the survey route if great horned owls (*Bubo virginianus*) or other predatory birds (e.g., goshawks) were heard in the area as soliciting a response from a spotted owl would put it in danger. Surveys continued when barred owls were observed as long as there was no immediate threat to a spotted owl. Surveys were not conducted if weather would hinder survey results or put the owls in danger (e.g. high winds, rain, snow, etc.).

Mesocarnivore Surveys

We utilized a non-rewarding baited hair snare and remote camera setup at each sampling location to determine species presence and to collect hair samples for genetic analysis. General areas to sample were randomly distributed throughout the project area. Selection of the best location to sample within those general areas were determined when in the field and based on the availability of proper diameter trees (<20" dbh), presence of game trails, general signs of wildlife use, and distance to edge habitat. Hair snares were of a similar design developed by Figura and Knox (2010) and consisted of two strips of corrugated plastic with five 30 mm gun cleaning brushes mounted to each strip. Strips were offset from each other, placed 10 cm apart, and the initial strip was placed 40 cm from the ground. To reduce the cost of genetic analysis, only samples that we thought to be red fox or fisher were collected for analysis. A metal utility box with holes punched in the box was placed approximately 15 cm above the highest strip (Figure 3). Boxes were baited with chicken and two vials of scent (Gusto and a red fox specific scent) which were placed behind the plastic strips. Remote cameras were programmed to take one picture per second and to take two pictures per trigger event. Each site was sampled for approximately four weeks and checked one time near the midpoint of the sampling timeframe to ensure bait and scent were still viable. Sites were sampled during the summer and winter seasons to help determine overall use by rare wildlife species. When installing, checking, or removing a sampling location, 10 minute area searches were conducted for potential fisher or red fox scat samples.

Figure 3. Bait station with hair snare used to capture genetic material and photographs of species utilizing this area of the forest.

Small Mammal & Rodent Surveys

We utilized perforated 3" x 3.75" Sherman live aluminum Kangaroo rat traps baited with peanut butter and oats to capture rodents and small mammals in the project area. A total of 48 transects (576 traps) were distributed throughout the project area with 37 transects located in the treatment area and 11 transects placed in a control area adjacent to the treatment area (Figure 4). Using ArcGIS, a grid was placed over the study area with grid points being separated by 100 meters. The 100 meter distance was selected because that is the average deer mouse home range which was the species we

expected to encounter most often (Blair 1942, Stickel 1968). Based on the placement of transects, and the distance between traps, we were expecting to obtain a complete census of the project area.

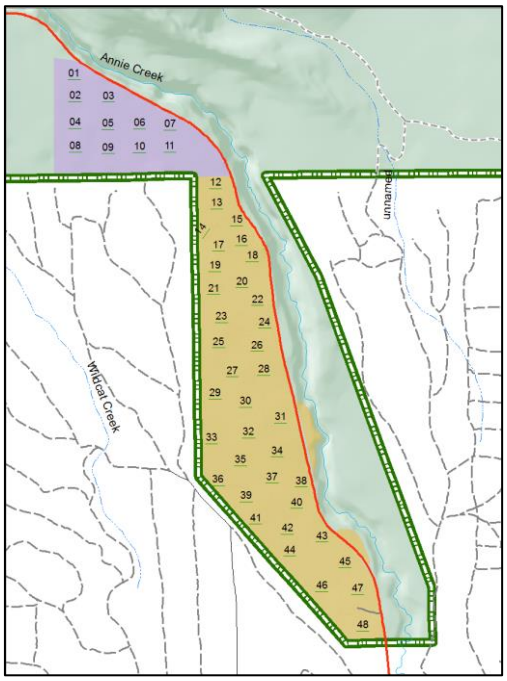

Figure 4. Location of the 48 transects used to sample the Panhandle for small mammals and rodents. The project area is shown in orange and the control area is shown in purple.

At each site, 15 traps were set up in a 100m x 50m grid with each trap along the transect separated by 25 meters (Figure 5). Traps were left set up at the sites for three consecutive days. Roth et al. (2007) noted that sampling longer than a three day period produced no noticeable increase in the number of captures. Traps were set up in the afternoon on day 1, between 1300 and 1400 hours. On days 2 and 3 traps were checked in the morning (~0700) and afternoon (~1400). On day 4 the traps were checked in the morning and then removed from the site. On a few occasions on days 2 and 3 traps had to be closed throughout the daytime period to prevent increased trapping mortality from warmer temperatures.

During setup, the vegetation and woody debris cover were classified both at the location of the trap and the surrounding area. Table 2 provides a description of classifications used for each location.

Each captured individual was marked using an 8mm passive integrated transponder (PIT tag) that was inserted subcutaneously in the interscapular area using a 16 GA needle and pushed laterally away from the injection site to minimize loss of the tag at the injection site. Each individual was scanned with a handheld reader prior to inserting the PIT tag to determine if this was an initial capture or a recapture. PIT tags are an effective alternative method when compared to ear tagging and toe clipping for marking small mammals (Schooley et al. 1993). This method of making was selected because it allowed us to reduce handling time of the mammal, was considered the least invasive method, and provides long-term monitoring benefits.

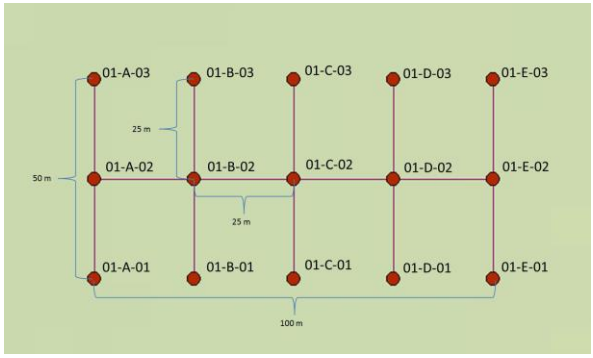

Figure 5. Example of the trap placement along a transect. Each trap is spaced 25m apart for a total of 15 traps to a transect. Each trap is labeled with the primary transect number (in this example 01), A-E for the secondary transect, and 1-3 for the trap number on the secondary transect.

Table 2. Classification groups for ground cover at the trap location and in the surrounding area.

Classification	Trap Location	Surrounding Area
1	In Open	Bare Ground / Litter / Duff
2	Next to Log	Grasses
3	Next to Lone Tree/Snag	Forbs
4	Under Trees	Shrubs
5	Under Seedling/Sapling	Heavy Woody Debris
6	Next to Stump	Seedling / Sapling Stand (lack of vegetation underneath)
7	Other	Seedling / Sapling Stand (grass/forb underneath)
8	NA	Other

Results

Northern Spotted Owl Survey

The survey route used to sample the Panhandle region of the Park consists of 7-9 calling points located along Highway 62 and USFS road 540. Prior to 2014 this route contained 7 calling stations along Highway 62. Two additional stations were added in 2014 near USFS road 540 to ensure adequate coverage of the area where the restoration project will be implemented. In total 29 surveys (10 day and 19 night) of this area have been completed since 2010. Table 3 provides a breakdown of the number of spotted owl surveys that have been completed each year at this site.

At no time during any of these surveys did we detect northern spotted owls or barred owls. The closest known location of spotted owls to the treatment area is the Annie Creek site which is approximately 1.5 km to the north and has not been active since 1996, likely due to the presence of barred owls in the area. Barred owls have been documented at the Annie Creek site on multiple occasions with the latest being a family group of barred owls in 2012.

Table 3. Number of surveys completed at calling stations along Highway 62 south and USFS road 540 between 2010 and 2015.

Time Period	2010	2011	2012	2013	2014	2015
Day Surveys	3	0	0	2	2	3
Night Surveys	0	6	6	4	3	0

Mesocarnivore Survey

Summer Surveys

During the summers of 2014 and 2015 we sampled 12 and 15 locations, respectively. Surveys were conducted between July 7th and November 12th. Of the 26 locations sampled, 18 were in the project area and 8 were in an area just outside the project area (Figure 6). We documented 11 unique species in 2014 and 12 in 2015 that included: 3 ungulate, 1 large carnivore, 5 mesocarnivores, 1 lagomorph, and 4 squirrel species (Table 4).

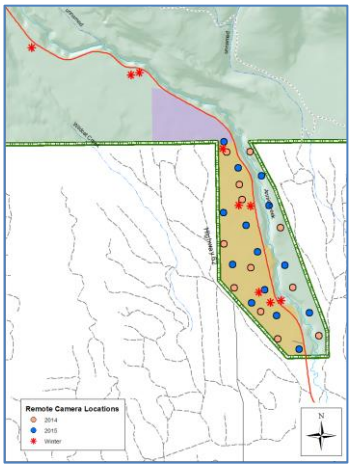

Figure 6. 2014 (orange) & 2015 (blue) summer camera locations and 2015 winter (red) camera locations.

Black bear (20 sites) and black-tailed deer (16 sites) were the dominant species documented at the 26 camera sets during the summer (Table 4). We did capture images of a fisher at one site that was likely a male, however we are still awaiting the results of genetic analysis to confirm our suspicions on the sex of this individual (Figure 7).

Table 4. Species documented with remote cameras during the summer of 2014 and 2015.

Common Name	Scientific Name	Documented in 2014	Documented in 2015	Total # of Sites Where Documented
Black Bear	*Ursus americanus*	Yes	Yes	20
Black-tailed Deer	*Odocoileus hemionus columbianus*	Yes	Yes	16
Bobcat	*Lynx rufus*	No	Yes	3
Coyote	*Canis latrans*	Yes	Yes	2

Table 4 cont. Species documented with remote cameras during the summer of 2014 and 2015.

Common Name	Scientific Name	Documented in 2014	Documented in 2015	Total # of Sites Where Documented
Douglas Squirrel	*Tamiasciurus douglasii*	Yes	No	5
Elk	*Cervus canadensis*	Yes	Yes	7
Fisher	*Pekania pennanti*	No	Yes	1
Golden-mantled Ground Squirrel	*Callospermophilus lateralis*	No	Yes	4
Northern Flying Squirrel	*Glaucomys sabrinus*	Yes	No	1
Mule Deer	*Odocoileus hemionus*	Yes	No	1
Pine Marten	*Martes martes*	Yes	No	1
Snowshoe Hare	*Lepus americanus*	Yes	No	1
Striped Skunk	*Mephitis mephitis*	No	Yes	4
Western Gray Squirrel	*Sciurus griseus*	Yes	Yes	2

Winter Surveys

Nine locations were selected for sampling during the 2015 winter with 6 of the 8 cameras being located in the project area and 3 of the cameras located just northwest of the project area (Figure 6). We documented 7 unique species in 2015 that included: 1 ungulate, 5 mesocarnivores, and 1 squirrel species (Table 5). Both fisher and red fox were documented during the winter surveys; however the sites where they were documented were outside the treatment area.

Table 5. Species observed along with the total number of sites where they were observed during the winter of 2015.

Common Name	Total # of Sites	Total # of Sites
Bobcat	*Lynx rufus*	1
Coyote	*Canis latrans*	4
Fisher	*Pekania pennanti*	1
Pine Marten	*Martes martes*	1
Red Fox	*Vulpes vulpes necator*	1
Elk	*Cervus canadensis*	2
Western Gray Squirrel	*Sciurus griseus*	1

Small Mammal & Rodent Survey

We sampled 48 transects with a total of 576 traps between May 6th and September 28th of 2015. We captured 5 unique species that included: deer mice, chipmunks, golden-mantled ground squirrels, western red-backed voles, and a western jumping mouse (Table 6). We had 232 captures of 144 unique individuals. Of the 144 unique individuals that were fitted with PIT tags, a total of approximately 20% were recaptured at least once.

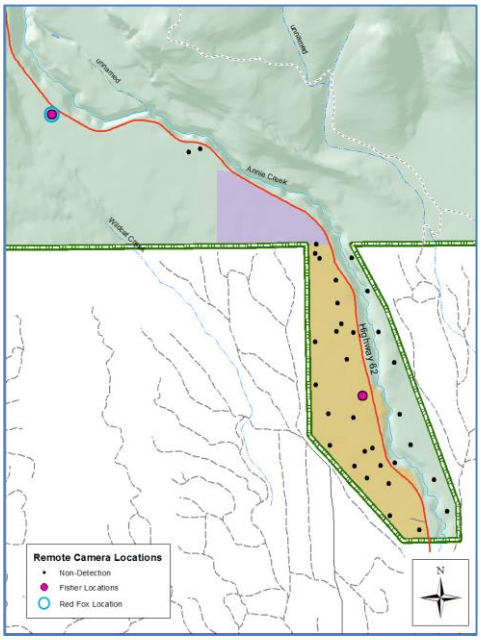

Figure 7. Location of fisher (pink) and red fox (blue) in and around the Panhandle during summer (south location) and winter surveys (north location).

Of the 232 captures, 10 (4.3%) were mortalities likely from heat or capture stress, 11 (4.7%) were not marked because they escaped before they could be tagged, 4 (1.7%) were not tagged because the animal appeared distressed, 3 (1.3%) were tagged but the PIT tag was read improperly, and 17 (7.3%) were not tagged because we originally did not plan on tagging chipmunks and golden-mantled ground squirrels.

Table 6. Species captured, number of times it was captured, and the average number per transect and trap in 2015.

Species	# Times Species Captured (includes recaptures)	# per Transect (%)	# per Trap (%)
Deer Mouse	110	2.292	0.191
Golden-mantled Ground Squirrel	42	0.875	0.073
Chipmunk	30	0.625	0.052
Western Red-backed Vole	4	0.083	0.007
Western Jumping Mouse	1	0.021	0.002

The distribution of these species varied considerably with deer mice (Figure 8) and chipmunks (Figure 9) being well distributed and abundant throughout the project area. Western red-backed voles (Figure 10) and Golden-mantled ground squirrels (Figure 11) appear to occur in isolated pockets within the study area. We only had 1 location where we captured western jumping mouse which was located in the only stand of aspen in the project area (Figure 12).

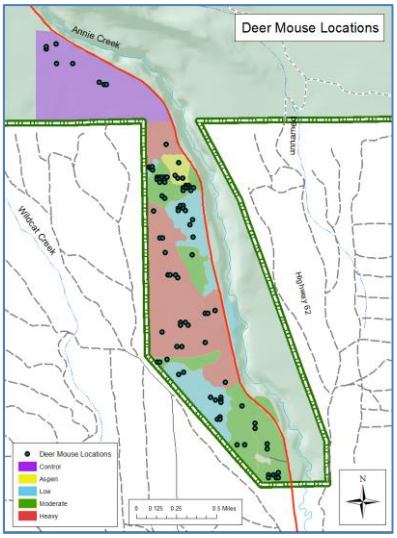

Figure 8. Locations where deer mice were captured in 2015.

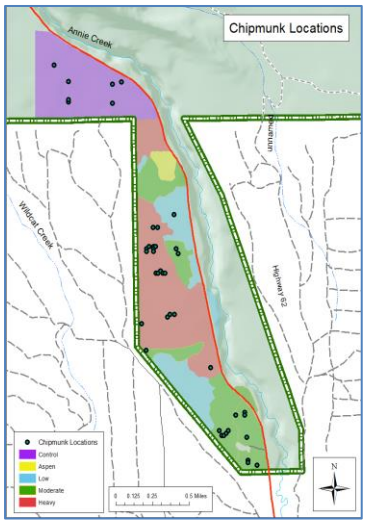

Figure 9. Locations where chipmunks were captured in 2015.

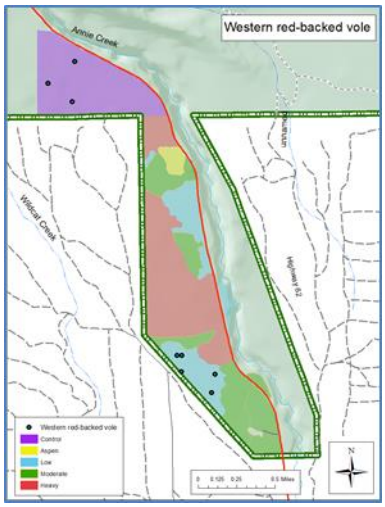

Figure 10. Locations where western red-backed voles were captured in 2015.

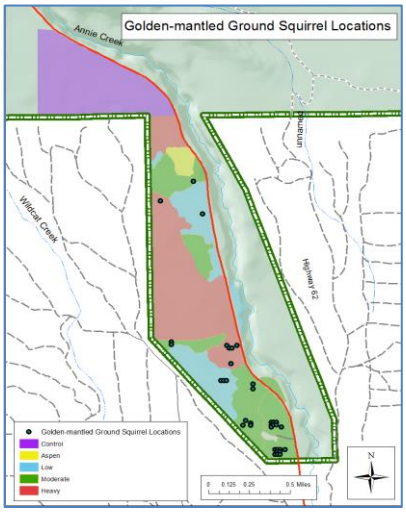

Figure 11. Locations where golden-mantled ground squirrels were captured in 2015.

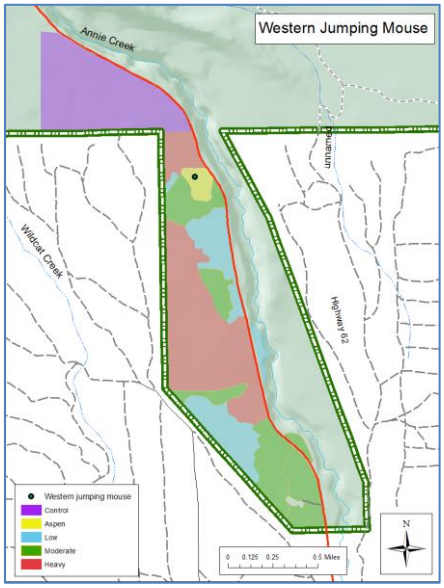

Figure 12. Locations where western jumping mice were captured in 2015.

Discussion

Spotted Owls

Spotted owls throughout the Pacific Northwest continue to decline with barred owl occupancy, habitat loss, and climate cited as the main causes for the drop in population size and distribution (Dugger et al. 2016). Habitat loss for spotted owls can occur in many ways, some of which include: high severity wildfire, loss of large trees due to lack of fire, timber harvest, and loss of prey availability. We have sampled the Panhandle region of Crater Lake National Park annually since 2010 and have not documented spotted or barred owls in or around the project area. The ultimate goal of the restoration project is to open up the understory to assist with the growth of large diameter ponderosa pine and encourage pine reproduction. Since spotted owls do not appear to be using this area of the Park we do not expect any negative short-term effects on spotted owls from this treatment. In the long-term, this treatment will help ensure the presence of large diameter trees and snags and will likely result in an increased prey base which are important elements when defining spotted owl habitat (USFWS 2011b).

Carnivores, Mesocarnivores, and Ungulates

As part of the remote camera inventory within the Panhandle area of the Park, we documented 1 carnivore (black bear), 6 mesocarnivores (coyote, bobcat, fisher, pine marten, Sierra Nevada red fox, and striped skunk), and 3 ungulates (black-tailed deer, mule deer, and elk).

Beginning in 2009, the Park began a research project to better understand the population size and distribution of black bears at Crater Lake National Park (George 2012). As part of this study, hair snares were distributed throughout the Park as part of a capture-recapture project to estimate density. It was determined that there was approximately 41 (CI 95% = 31-72) bears ocupying the Park. As part of this study, 10 black bears (3 males and 7 females) were fitted with radio collars and tracked for 2 years (Mohren et al. *in press*). The telemetry study showed the area in and around the Panhandle is utilized by black bears and that some of those bears also use the area for denning. As part of this project we observed 2 den sites in 2013 and 2014, in both cases black bears utilized a large (>100 ft tall) live ponderosa pine tree that had been hollowed out by fire. If we examine the number of black bear events per camera deployed during the Panhandle project and compare that to the number of black bear events per camera deployed as part of a Park wide inventory (Mohren 2015b, Mohren 2015c), it does appear that black bears are more often observed in the Panhandle area of the Park versus any other area. Based on the diversity of treatments to be implemented, the overall distribution of black bear throughout Crater Lake National Park, and the restoration goals of this project to maintain large diameter trees and integrate fire back into this ecosystem, it is suspected black bears will benefit from this project.

Mesocarnivores tend to be more numerous in species richness, have more diverse behavior patterns, use a greater diversity of habitats, and are generally more abundant than large carnivores yet we know very little about their influence on the ecosystem at Crater Lake National Park (Roemer et al. 2009). Beginning in 2014, the wildlife team at Crater Lake National Park utilized 171 non-rewarding baited camera stations spread throughout the Park to document mesocarnivore presence and

distribution (Mohren 2015b, Mohren 2015c,). This body of work demonstrates pine martens, coyotes, and bobcats are well distributed throughout the Park. However the distribution of fisher, Sierra Nevada red fox and stripped skunk is still unknown due to a limited number of observations. As part of this project we documented fisher, pine marten, and Sierra Nevada red fox in or around the Panhandle in both the summer and winter seasons. It is clear from our inventories that this area is being utilized by these species and we will need to take that into consideration when developing the forest restoration project. For most of these species, large diameter tree and snag retention and coarse down wood play a vital role for denning, resting, and foraging sites (Aubrey et al. 2013, USFWS 2014). One of the goals of this project is to reduce forest density to allow for the growth of larger diameter ponderosa pines (and eventually snags) which are important habitat components for these rare species. Additionally, retaining the current density of snags and woody debris and increasing shrub cover for prey species by opening up the canopy cover will likely benefit these species.

There have been multiple studies on ungulate species at Crater Lake National Park (NPS 1939, Wallis 1947, Hill 1976, Jenkins et al. 1988, Mark 1995, Mohren 2015b, Mohren 2015c) which clearly show elk and black-tailed deer are well distributed throughout all areas of the Park. Mule deer on the other hand are largely concentrated in the eastern portions of the Park (Mohren 2015b, Mohren 2015c) and the distribution of white-tailed deer is largely unknown but thought to be focused in the western portions of the Park. It is highly probable that this restoration project, combined with prescribed fire will increase foraging quality and quantity for ungulates in this area (Edge et al. 1987). Reducing forest density in areas of the Panhandle will likely promote the growth of shrub species providing excellent escape cover and cover for fawning. Lastly, because of the diversity of treatment types with some areas not being treated or only receiving light treatment, thermal cover should be readily available. For these reasons we do not feel there will be any significant impacts to ungulate species as part of this project.

Small Mammals and Rodents

Small mammals and rodents play an important role in maintaining a healthy ecosystem at Crater Lake National Park. They are a critical prey item, distribute seeds and nuts throughout the forest, aerate the soil through tunnel and burrow development, and assist with fungus distribution. At the end of this forest restoration project we expect to see an overall increase in small mammal and rodent biomass as noted by several studies on forest fuels reduction (Converse et al. 2006, Amacher et al. 2008, Bagne 2010).

Deer mice were the most abundant and widely disbursed species trapped as part of this project. Much of the literature on forest fuels reduction and deer mice shows an increase in population size following a treatment event (Converse et al. 2006, Amacher et al. 2008, Bagne 2010) and we would expect to see the same result from our forest restoration project.

As we open the canopy, we will likely get an increase in grass species which may help improve the jumping mouse (*Zapus spp.)* population, as jumping mice have been shown to prefer grassy habitats (Quimby 1951). Only one jumping mouse was caught this year and it was in the Panhandle's aspen/cottonwood riparian stand, the site in the Panhandle with the highest grass cover. Aspen stands

have been shown to be areas of high species richness and diversity and have been referred to as "hot spots" for small mammals (Oaten and Larsen 2008). To help this species it is recommended that the small aspen/cottonwood stand in this area be restored to maintain and promote the native perennial grass and riparian habitats that occur in this area. Removing encroaching conifers and reintroducing fire into this microhabitat will likely improve the jumping mouse population along with other small mammal and rodent populations in this area.

Only one vole species, the western red-backed vole, was captured in the Panhandle and it appears to have a very limited distribution having only been documented in the "control" area of the project and in one location on the southwest side of the project area. It has been shown that western red-backed voles will likely decrease in a short post-burn survey period (Suzuki and Hayes 2003) and the same is likely to occur with this restoration effort. Western red-backed voles prefer more mesic areas and reducing canopy cover will likely alter the microhabitat and increase diurnal heating and drying in areas where they are located. While their numbers would be expected to increase over time, it's been noted that any noticeable increase most likely won't be observed for at least 3 years post-treatment (Krefting and Ahlgren 1974; Simon et al. 1998). The pocket of habitat where these species are located is also located in an area slated for a "low" level of treatment. To help ensure we provide opportunities for this species to persist in the Panhandle it is recommended that treatments include some aspect of a "Reserve / Retention Patch" treatment type within western red-backed vole habitat. This will ensure the area this species occupies is protected.

There will likely be little or no negative effect of this forest restoration project on golden-mantled ground squirrels within the Panhandle. Shick et al. (2006) suggests treatments that open the understory of ponderosa pine stands while maintaining mature pines similar to historic conditions may increase golden-mantled ground squirrel populations. Kalies and Covington (2012) observed an increase in golden-mantled ground squirrel densities and biomass after thinning occurred. Lastly, S.J. Converse (2005) noted that there was no change in densities of golden-mantled ground squirrels in response to forest treatments. The golden-mantled ground squirrel is often found in open understory and rocky environments. However, the majority of sites where golden-mantled ground squirrels were captured at Crater Lake National Park contained a significant amount of shrub cover. Shrub species can be found in areas of the Panhandle where canopy cover is reduced, which generally occurs along the forest edge and near the NPS maintenance yard. As we begin to open up the forest canopy we would expect to see an increase in shrub cover over the long-term. If the shrub community is maintained in the Panhandle we will likely see little or no long-term negative effects to the golden-mantled ground squirrel population.

Much of the scientific literature shows chipmunks have a positive response to forest thinning treatments (Carey 2001, Carey and Wilson 2001, Sullivan et al. 2001, Hadley and Wilson 2004). There is no reason to believe we would not see a similar response of chipmunks within the Panhandle. This group of species appears to be well distributed throughout the project area and the diversity in treatment types will likely help this species respond positively to the restoration efforts. One of the goals of this restoration effort is to open up the forest canopy to promote the growth of

large diameter trees and a diverse understory. This will benefit the yellow-pine chipmunk which prefers a more open canopy, xeric habitat (Koehler and Hornocker 1977).

Conclusion

Based on our findings and on the general idea about what type of forest restoration activities will occur in this study area we recommend the following:

- Snag and down wood retention will be a critical component of ensuring this project is beneficial to wildlife species. To help ensure the Panhandle continues to be a suitable area for species such as fisher, red fox, pine marten, and several small mammal species, retention of most snags and down wood greater than 15 inches in diameter should occur. Removal of some snags and down wood for operational needs or safety concerns would not contribute significantly to a decline in the species we studied.

- Western red-backed voles occur in only a small pocket of habitat within the project area. This species is generally associated with more mesic sites and has been shown to decline when canopy cover is decreased. To ensure the viability of this population we recommend making portions of the area where this species occurs a "Reserve / Retention" treatment type.

- Greenleaf manzanita and tobacco brush are the dominant shrub cover in this region which provides an important cover component to many species such as golden-mantled ground squirrels, lagomorph species, and ungulates. Retention of this shrub community should remain to ensure escape cover from predators and cover for fawning is available. It is expected that opening up the canopy will potentially increase the distribution and density of shrub cover, especially if the rehabilitation project is followed up with prescribed burning.

- Ensuring the persistence of the cottonwood / aspen habitat within the Panhandle area by reducing competition from conifers in and around the hardwood community and ensuring long-term maintenance of the area through fire management will play a significant role in providing habitat that is beneficial to many species in this unique habitat type including the western jumping mouse.

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